Modeling the marine Nd isotope variability with an offline Ocean General Circulation Model

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Neodymium isotope ratios of authigenic phases in marine archives have garnered increased attention because of their usefulness as tracers of past changes in ocean circulation. Such applications assume that Nd isotopes in deep waters mainly reflect mixing of water masses that are “tagged” with distinct Nd isotope ratios in source regions.

In order to evaluate how well this simple assumption of “quasi-conservative mixing” reflects the complicated reality of general circulation in the oceans, we present numerical simulations for the Nd isotope distribution in seawater using an offline ocean general circulation model (OGCM).

Our input parameters are Nd isotope data from modern surface waters. These data are used to generate an interpolated Nd isotope map for the entire surface ocean, which is treated as a fixed surface boundary condition. Nd isotope ratios are treated as a passive tracer, which are propagated into the interior ocean by the advective-diffusive transport of the OGCM until a steady state is reached. This approach was chosen to because it mimics the behaviour of well-known and well understood conservative tracers, such as potential temperature and salinity. We then compare the model results for non-surface grid points to published data.

The simple approach outlined above (Experiment 1) produces Nd isotope ratios for North Atlantic Deep Water that are consistent with observations, but produces values lower than observed in the deep Pacific. This indicates a need for a source of more radiogenic Nd directly to the deep Pacific Ocean. If we modify the input (Experiment 2) by fixing the Nd isotope ratio of the deep Pacific Ocean to a value that is consistent with observations, the global results are brought into close agreement with deep seawater data—more than half of the model estimates are within one epsilon unit of the observations.

Our results thus indicate that (1) the deep Pacific requires a source of radiogenic Nd in addition to the inputs from the surface, and (2) that when the North Atlantic and North Pacific are set with realistic values, a majority of intermediate areas are consistent with quasi-conservative mixing of these two end-members.

Plagiogranitic, serpentinite and carbonate veins in abyssal peridotites: Insights into fluid transport in a detachment fault setting (ODP Leg 209)

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Abyssal peridotites are tectonically denuded to the sea-floor by extensive normal faulting during magma-limited spreading at slow and ultra-slow spreading mid-ocean ridges. Their alteration is a complex multistage process, ranging from interaction with plagiogranitic melts at high temperatures (>800 °C) to subgreenschist-facies alteration near the seafloor. These processes are recorded in several generations of alteration veins, which we have studied in serpentinized harzburgites from the Mid-Atlantic Ridge (ODP Leg 209).

Chlorite-actinolite-bearing veins containing accessory zircon are bound to semi-brittle shear zones. Ti-in-zircon thermometry yields temperatures of 720–830 °C, interpreted as crystallization temperature of precursor plagiogranitic melts. Melt impregnations were altered at T= 250–400 °C; reaction path modelling suggests that the observed alteration assemblage can be produced by interactions with fluids that are buffered by serpentinization reactions. Chlorite-bearing veins are crosscut by picrolite and carbonate veins, the latter subdivided into three types: (i) pure dolomite veins, (ii) pure calcite veins, and (iii) calcite veins containing euhedral dolomite crystals. O isotopes of calcite veins indicate formation temperatures of 90–185 °C (assuming a fluid δ^{18} of 1.5).

The presence of plagiogranitic melts in detachment fault rocks showing localized ductile and semi-brittle deformation textures is contrasted by the lack of such melts in areas of more diffuse, non-localized ductile deformation. Temperatures of ca. 800 °C deduced from Ti-in-zircon put a lower boundary on the temperature of initial fracturing in the lithosphere. We propose that evolved melts only formed where the detachment fault cuts gabbroic lithologies and where seawater-derived fluids are present. Down to subgreenschist-facies conditions, the fault remained the locus of fluid flow. The carbonate O-Sr-Li isotopic data suggest, however, that upward migrating fluids underwent conductive cooling indicative of very slow fluid flow.